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BACTERIOLOGICAL WATER QUALITY OF TULPEHOCKEN CREEK BASIN, BERKS--ETC(U)
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Water-Resources Investigations 78-53

Prepared in cooperation with the U.S. Army Corps of Engineers

BACTERIOLOGICAL WATER-QUALITY OF TULPEHOCKEN CREEK BASIN, BERKS AND LEBANON COUNTIES, PENNSYLVANIA

April, 1978

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A four month intensive study of the bacteriological quality of water in the Tulpehocken Creek basin indicates that (1) the streams locally contain high densities of bacteria indicative of fecal contamination, (2) nonpoint waste sources, particularly livestock, are the dominant influence in the excessive bacteriological-indicator counts observed, and (3) retention time of water in the proposed Blue Marsh Lake is believed sufficient to reduce bacteria densities to acceptable levels except following intense rainfall and runoff events during normally low flow periods.

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FACTORS FOR CONVERTING U.S. CUSTOMARY UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

Multiply U.S. Customary units	By	To obtain (SI) units
Feet (ft)	.3048	Meters (m)
Miles (mi)	1.609	Kilometers (km)
Square Mile (mi^2)	2.590	Square kilometer (km^2)
Million gallons per day (mgal/d)	1.54723	Cubic ft/second (ft^3/s)
Ounce avoirdupois (oz avdp)	0.03527	Grams (g)

BACTERIOLOGICAL WATER QUALITY OF TULPEHOCKEN CREEK BASIN,

BERKS AND LEBANON COUNTIES, PENNSYLVANIA

By James L. Barker

ABSTRACT

A four month intensive study of the bacteriological quality of water in the Tulpehocken Creek basin indicates that (1) the streams locally contain high densities of bacteria indicative of fecal contamination, (2) nonpoint waste sources, particularly livestock, are the dominant influence in the excessive bacteriological-indicator counts observed, and (3) retention time of water in the proposed Blue Marsh Lake is believed sufficient to reduce bacteria densities to acceptable levels except following intense rainfall and runoff events during normally low flow periods.

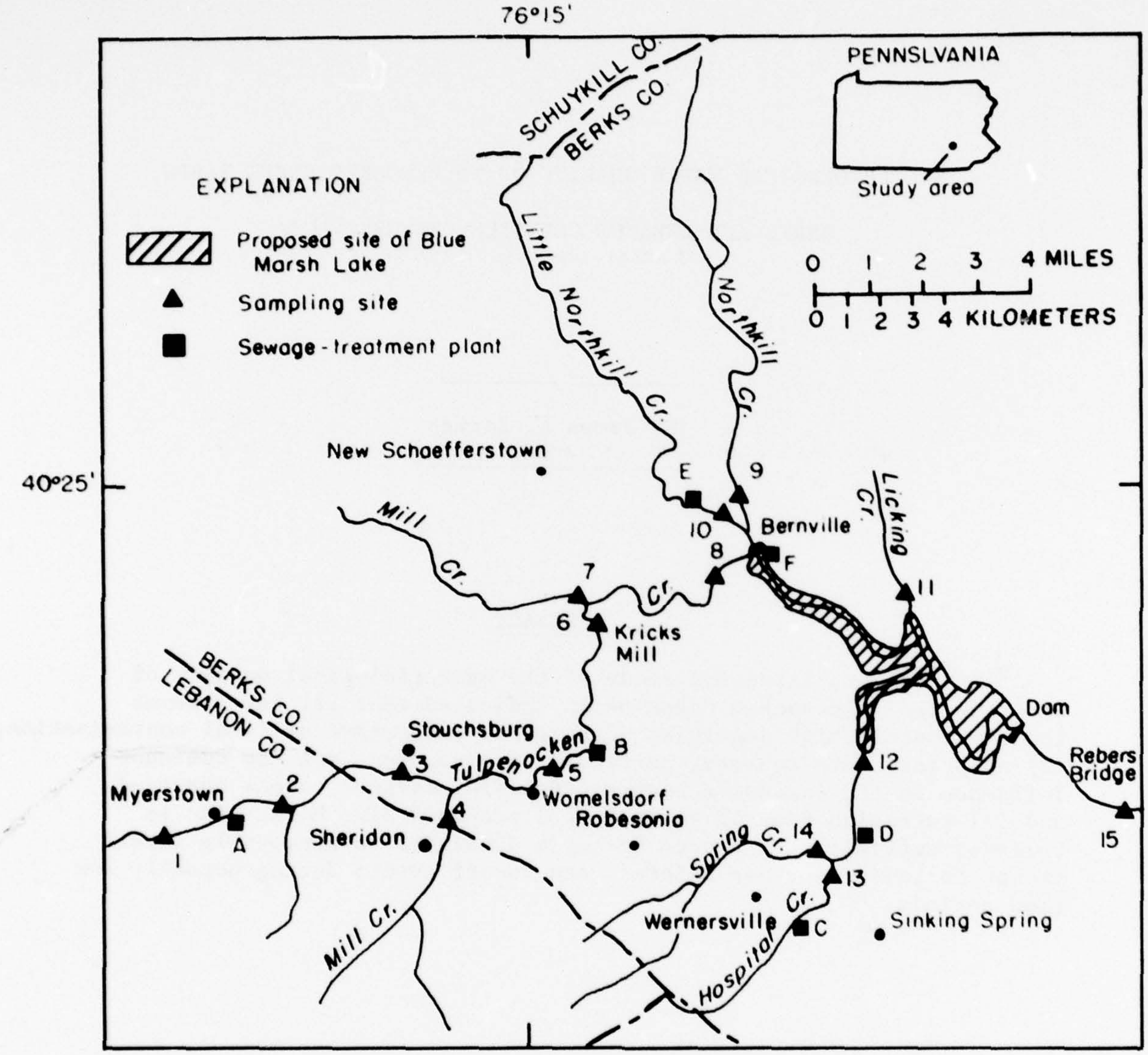

Figure 1.--Tulpehocken Creek Basin study area. Numbers refer to sampling sites given on page 4 and letters refer to sewage-treatment plants given on page 5.

PURPOSE AND SCOPE

The preimpoundment investigation of water quality in the Tulpehocken Creek basin was begun by the U.S. Geological Survey (USGS) in June 1972 at the request of the Philadelphia District, U.S. Army Corps of Engineers. The purpose of the investigation was to collect base-line water-quality information for Tulpehocken Creek and its major tributaries pertinent to the water quality of the proposed Blue Marsh Lake.

Bacteriological data collected since June 1972 indicated that populations of intestinal bacteria generally exceed the State and Federal recommended standards for public water supply and water-contact recreation (Barker, 1977). The bacterial populations suggestive of recent fecal contamination prompted the U.S. Army Corps of Engineers to request the USGS to gather additional information on the point and nonpoint sources of enteric bacteria.

The present investigation was designed to obtain densities of fecal coliform and fecal streptococci populations at fifteen selected sites on Tulpehocken Creek and its major tributaries, to identify the areas and sources of major fecal contamination, and to determine the extent of temporal variation in these populations during June to September, the water-contact recreation season.

DESCRIPTION OF AREA

The study area includes Tulpehocken Creek and its major tributaries from the headwaters near Myerstown, to a point about 28 miles downstream near the Blue Marsh Lake Dam (Figure 1). The drainage area is 175 mi^2 in parts of Berks and Lebanon Counties.

The basin is predominantly agricultural but includes the villages of Wernersville, Robesonia, Womelsdorf, Mt. Pleasant, Bernville, Sheridan, Stouchsburg, New Schafferstown and Myerstown. Additional information on the Tulpehocken Creek Basin is published in Biesecker and others (1968) and Barker (1977).

METHODS OF STUDY

Biweekly samples for the determination of enteric bacterial densities were collected 10 times during the period June 1 to September 21, 1977. Sampling was conducted during low to moderate flows. Water temperature, pH, specific conductance, and relative turbidity were measured at time of collection.

Stream samples were collected at the following 15 locations on Tulpehocken Creek and its major tributaries (see figure 1):

Site No. 1. Tulpehocken Creek upstream from Myerstown

2. Tulpehocken Creek downstream from Myerstown

3. Tulpehocken Creek at Stouchsburg

4. Mill Creek at Sheridan

5. Tulpehocken Creek at Route 419, Womelsdorf

6. Tulpehocken Creek at Kricks Mill, USGS gage 01470779

7. Mill Creek near Kricks Mill

8. Tulpehocken Creek at Bernville, USGS gage 01470800

9. Northkill Creek at Route 183, Bernville

10. Little Northkill Creek upstream of Bernville

11. Licking Creek at Mt. Pleasant

12. Spring Creek at Peacock bridge

13. Hospital Creek at Wernersville

14. Spring Creek near Robesonia

15. Tulpehocken Creek at Rebers bridge

All samples were collected and analyzed for enteric bacteria by the membrane filtration method, as described in the 14th edition of "Standard Methods for the Examination of Water and Wastewater" (American Public Health Association and others, 1976).

Point source samples were collected at six waste-treatment plants by personnel of the Philadelphia District, U.S. Army Corps of Engineers. These samples were also analyzed by methods described in "Standard Methods...," except that the samples were held overnight prior to incubation.

PRESENTATION OF DATA AND DISCUSSION

Major Point Sources

Known point sources of treated domestic sanitary waste include sewage-treatment plants at Myerstown, Womelsdorf, Wernersville State Hospital, Wernersville-Robesonia, Heidelberg Country Club, and Bernville. (See figure 1).

The approximate waste loads at the sewage-treatment plants are as follows:

MAP LETTER	PLANT	LOAD (Mgal/d)	STREAM DISTANCE FROM LAKE (mi)
A	Myerstown	.35	16.7
B	Womelsdorf	.13	9.1
C	Wernersville State Hospital	.08	3.8
D	Wernersville-Robesonia	.35	2.4
E	Heidelberg County Club	.015	2.2
F	Bernville	.054	1.7

Bacteriological data collected at each of the above point sources are presented in table 1. In addition to sampling the waste effluents, each receiving stream was sampled eight times between May 31, 1977 and September 26, 1977, approximately 20 feet upstream and downstream from each effluent discharge.

Fecal coliform and fecal streptococcus densities of the treatment-plant effluents indicate that, with few exceptions, sufficient residual chlorine is being used to reduce bacterial populations to acceptable levels. Principal among these was the generally high incidence of excessive densities in the effluent at the Wernersville-Robesonia plant. Data from the Bernville plant and the Heidelberg Country Club revealed less-frequent high densities.

Table 1.--Summary of Point Waste Source Sampling

[Samples collected and analysed by the U. S. Army Corps of Engineers, Philadelphia District. FC, fecal coliform per 100 mL; FS, fecal streptococcus per 100 mL; TNTC, too numerous to count]

Treatment Plant	Sampling Point	5-31-77		6-13-77		6-28-77		7-5-77	
		FC	FS	FC	FS	FC	FS	FC	FS
Myerstown	Upstream	430	410	120	420	2200	3400	0	260
	Effluent	0	10	0	80	0	0	0	0
	Downstream	0	360	0	20	3200	3800	0	0
Wernerville State Hosp	Upstream	230	400	480	500	100	1900	0	0
	Effluent	0	0	0	0	0	100	0	0
	Downstream	190	760	420	440	100	700	0	0
Wormelsdorf	Upstream	1100	700	1200	1200	36000	38000	0	86
	Effluent	0	0	20	0	0	100	0	0
	Downstream	1100	680	900	620	3500	400	0	172
Wernersville-Robesonia	Upstream	1600	1600	1100	1000	2500	4700	0	86
	Effluent	0	0	TNTC	TNTC	0	100	24000	22000
	Downstream	1200	1200	3400	9300	11000	3100	690	1800
Heidelberg Country Club	Upstream	840	710	360	680	300	0	0	0
	Effluent	10	10	0	0	7800	14000	0	0
	Downstream	730	640	280	1000	11000	15000	0	86
Bernville	Upstream	1500	1200	1100	400	12000	25000	86	86
	Effluent	TNTC	TNTC	160	100	100	100	0	0
	Downstream	1900	840	300	180	11000	23000	0	0

Treatment Plant	Sampling Point	8-22-77		8-29-77		9-12-77		9-26-77	
		FC	FS	FC	FS	FC	FS	FC	FS
Myerstown	Upstream	0	600	0	0	0	200	38000	61000
	Effluent	18000	8500	0	5400	0	0	26000	49000
	Downstream	2700	3800	0	800	0	0	36000	57000
Wernerville State Hosp	Upstream	0	400	100	400	0	300	100	1900
	Effluent	0	200	0	0	0	0	56000	17000
	Downstream	0	0	0	0	0	0	400	2300
Wormelsdorf	Upstream	800	1600	0	0	100	400	28000	49000
	Effluent	0	500	200	0	0	0	200	500
	Downstream	1300	68000	300	0	0	0	26000	53000
Wernersville-Robesonia	Upstream	1	1300	400	200	500	800	6300	9300
	Effluent	81000	36000	99000	35000	39000	3000	200	700
	Downstream	18000	7200	300	200	8700	6200	7700	9900
Heidelberg Country Club	Upstream	0	500	400	100	0	200	20000	53000
	Effluent	0	1400	200	100	0	0	4600	11000
	Downstream	0	300	100	400	200	0	25000	52000
Bernville	Upstream	0	1100	0	200	0	400	17000	57000
	Effluent	3000	17000	61000	29000	0	0	100	400
	Downstream	-	21000	7800	7000	0	0	14000	TNTC

NONPOINT SOURCES

Densities of enteric bacteria in runoff are influenced by factors such as rainfall, stream hydrology, sediment concentration, and human and animal populations. The majority of human population centers have sewage-treatment facilities to control bacteria. Animal populations, particularly livestock, contribute a significant number of enteric bacteria to the environment. Estimates of the contribution of indicator bacteria by some common livestock in the Tulpehocken Creek basin on the basis of the 1976 Livestock Report are given in table 2. Even if the number of bacteria reaching the stream during a rainstorm is only 1 to 6 percent of the estimated contribution as suggested by Beane and others (1977), the number of bacteria reaching the stream is still large and represents a major source of fecal contamination.

Results of the June to September fecal coliform and fecal streptococci sampling are summarized in table 3. A complete tabulation of data collected during the period is listed in table 4. Table 3 shows that the geometric means of samples collected at all 15 sites exceeded the current U.S. Environmental Protection Agency and Pennsylvania Department of Environmental Resources bathing-water criterion of a geometric mean of 200 fecal coliform per 100 mL. However, retention time of the water in the lake is believed sufficient to reduce these bacteria densities to acceptable levels except following intense rainfall and runoff during normally low flow periods.

Sampling stations at which high densities of fecal coliform or fecal streptococci bacteria were observed in all samples included station 4, Mill Creek at Sheridan; station 5, Tulpehocken Creek at Womelsdorf; station 7, Mill Creek near Kricks Mill; and station 14, Spring Creek near Wernersville.

The populations of indicator bacteria observed in a stream is dependent on many environmental factors. Variations in the transport media--streamflow and sediment--explain a portion of the variability shown by the standard deviations in table 3.

Table 2.--Estimated daily contribution, in millions, of indicator bacteria from some livestock in Tulpehocken Creek Basin 1/

Livestock	Estimated number of animals in basin	Average wet weight of feces per 24 hours (grams)	Average Density per gram of feces 2/ (million)		Average Contribution per capita per 24 hours (million)		Estimated contribution of indicator bacteria from livestock per 24 hours	
			Fecal Coliform	Fecal Strepto-cocci	Fecal Coliform	Fecal Strepto-cocci	Fecal Coliform	Fecal Streptococci
Hogs and pigs	13,000	2,700	3.3	84.0	8,900	230,000	116×10^{12}	$2,990 \times 10^{12}$
Cattle and calves	26,000	23,600	.23	1.3	5,400	31,000	140×10^{12}	806×10^{12}
Chickens and Turkeys	147,000	315	.80	3.1	185	960	27×10^{12}	141×10^{12}

1/ Based upon percentage of basin in Berks and Lebanon Counties as reported in Livestock Annual Summary (1976).

2/ Coliform and streptococci data from Geldreich, 1966.

Table 3.--Summary of fecal coliform (FC) and fecal streptococci (FS) concentrations in the Tulpehocken Creek Basin

Station		Geometric mean	Standard deviation	Range
1	FC	1000	3300	200 - 8600
	FS	1200	800	340 - 3200
2	FC	6600	68000	2300 - 220,000
	FS	4200	20000	1300 - 67,000
3	FC	6100	4300	2500 - 15,000
	FS	9800	46000	2700 - 150,000
4	FC	12000	28000	3900 - 89,000
	FS	8700	22000	1800 - 48,000
5	FC	13000	50000	3200 - 160,000
	FS	13000	64000	2100 - >200,000
6	FC	6500	36000	1000 - 120,000
	FS	9800	61000	980 - >200,000
7	FC	28000	21000	8000 - 79,000
	FS	39000	82000	8600 - 230,000
8	FC	6800	77000	1900 - 250,000
	FS	7700	30000	1900 - >100,000
9	FC	4400	60000	1900 - 23,000
	FS	6300	13000	1500 - 44,000
10	FC	2400	5400	800 - 19,000
	FS	5800	28000	2700 - >87,000
11	FC	4700	11000	970 - 37,000
	FS	4200	2800	3200 - 12,000
12	FC	3800	9700	1300 - 33,000
	FS	7700	17000	1700 - >50,000
13	FC	2100	8000	400 - 26,000
	FS	3800	5100	1400 - 17,000
14	FC	11000	21000	1800 - 73,000
	FS	31000	33000	5600 - 96,000
15	FC	3600	16000	700 - 48,000
	FS	9000	88000	1000 - 280,000

Table 4.--Physical and bacteriological analyses of samples collected in the Tulpehocken Creek Basin.

Date Mo Day Yr	Water temperature (°C)	Discharge (ft 3/S)	pH (units)	Turbidity*	Specific conductance (micromhos per centimeter at 25°C)	FC/FS	Fecal coliform (col./100mL)	Fecal Streptococci (col./100mL)
Site 1.--Tulpehocken Creek Upstream of Myerstown								
6-01-77	17.5		8.0	2	505	2.7	8,600	3,200
6-15-77	19.5		8.0	1	535	3.2	4,100	1,300
6-29-77	19.0		8.1	2	525	1.5	1,400	900
7-13-77	20.0		7.2	2	510	5.9	8,300	1,400
7-26-77	20.0		8.3	2	540	0.3	700	2,100
8-10-77	18.0		-	1	540	0.3	380	1,100
8-23-77	18.0		8.1	1	535	1.8	600	340**
8-30-77	17.0		7.6	0	520	0.2	250	1,500
9-07-77	16.5		7.8	0	600	0.4	460	1,100
9-21-77	16.0		7.4	1	550	0.3	200	680
Site 2.--Tulpehocken Creek Downstream of Myerstown								
6-01-77	17.0		7.6	1	420	1.8	2,300	1,300
6-15-77	19.0		7.5	3	580	0.7	3,900	5,300
6-29-77	19.5		7.9	3	525	1.5	11,000	7,300
7-13-77	21.5		7.5	3	475	3.3	220,000	67,000
7-26-77	20.0		8.3	2	550	1.3	2,400	1,800
8-10-77	19.0		-	2	560	0.8	2,700	3,600
8-23-77	18.0		7.8	2	565	0.3	11,000	3,600
8-30-77	19.5		7.6	1	565	1.4	5,900	4,100
9-07-77	17.5		7.6	1	565	0.5	6,300	12,000
9-21-77	17.0		7.3	1	558	.6	2,900	4,500

			Site 3.--Tulpehocken Creek at Stouchsburg				
6-01-77	18.0	7.8	2	450	0.8	10,000	12,000
6-15-77	18.5	7.7	3	540	0.4	6,600	15,000
6-29-77	21.0	7.6	3	520	0.4	11,000	29,000
7-13-77	21.5	7.4	3	458	0.1	8,000	150,000
7-26-77	21.5	8.4	2	520	2.3	4,200	1,800
8-10-77	19.5	-	3	520	1.0	2,600	2,700
8-23-77	19.0	8.0	2	530	2.3	10,000	4,300
8-30-77	20.0	7.7	2	542	0.8	2,500	3,100
9-07-77	18.0	7.6	1	520	0.3	15,000	45,000
9-21-77	17.5	7.3	1	541	0.8	2,900	3,500
			Site 4.--Mill Creek at Sheridan				
6-01-77	17.0	7.5	2	370	1.9	7,000	3,700
6-15-77	17.0	7.8	3	450	0.9	6,700	7,400
6-29-77	21.0	7.7	3	450	0.9	43,000	48,000
7-13-77	21.5	7.3	2	415	1.0	42,000	63,000
7-26-77	20.0	8.3	3	450	3.1	89,000	29,000
8-10-77	21.0	-	3	450	1.1	6,300	6,000
8-23-77	18.0	8.3	2	470	0.9	17,000	1,800**
8-30-77	21.5	8,0	3	455	1.0	3,900	3,800
9-07-77	18.0	7.7	1	525	0.9	6,200	7,000
9-21-77	17.0	7.3	1	490	1.3	4,500	3,400
			Site 5.--Tulpehocken Creek at Rt 419, Womelsdorf				
6-01-77	17.0	8.0	2	490	0.3	4,000	16,000
6-15-77	19.0	7.8	3	490	1.5	10,000	6,400
6-29-77	19.5	7.6	3	480	0.7	14,000	21,000
7-13-77	24.0	7.1	4	349	<.8	160,000	>200,000**
7-26-77	21.0	7.9	3	480	0.9	73,000	86,000
8-10-77	22.0	-	3	440	1.0	4,000	4,200
8-23-77	19.0	7.9	2	525	5.0	14,000	2,800**
8-30-77	21.5	8.0	2	515	2.5	5,500	2,200
9-07-77	19.0	7.8	2	550	0.4	31,000	74,000
9-21-77	18.0	7.5	2	555	1.5	3,200	2,100

* Severity code 0=None, 1=Mild, 2=Moderate, 3=Serious, 4=Severe
** Best estimate based upon nonideal counting conditions

Table 4.--Physical and Bacteriological Analyses--Continued

Date Mo Day Yr	Water temperature (°C)	Discharge (ft 3/S)	pH (units)	Turbidity*	Specific conductance (micromhos per centimeter at 25°C)	FC/FS	Fecal coliform (col./100mL)	Fecal Streptococci (col./100mL)
				Site 6.--Tulpehocken Creek at Kricks Mill				
6-01-77	17.0	67	7.6	2	460	1.2	1,200	980
6-15-77	18.0	67	7.7	3	500	1.1	3,500	3,300
6-29-77	21.0	64	7.9	3	470	0.5	14,000	29,000
7-13-77	23.5	163	6.8	4	295	< .8	120,000**	>200,000**
7-26-77	20.0	62	8.1	3	480	0.6	18,000	32,000
8-10-77	23.5	48	-	2	510	0.2	1,000**	4,400
8-23-77	20.5	52	7.9	2	500	6.7	28,000	4,200
8-30-77	23.5	46	8.1	3	520	0.5	1,000**	2,200
9-07-77	20.0	51	7.9	2	505	0.4	9,300	24,000
9-21-77	19.0	44	7.6	1	555	2.8	3,900	1,400
				Site 7.--Mill Creek near Kricks Mill				
6-01-77	18.0		7.9	2	322	3.1	40,000**	13,000
6-15-77	20.0		7.8	3	350	0.5	23,000	51,000
6-29-77	22.0		8.0	3	350	0.6	34,000	54,000
7-13-77	24.0		6.6	2	275	-	53,000	>200,000
7-26-77	22.0		8.4	1	330	0.7	79,000	110,000
8-10-77	23.0		-	2	350	3.2	35,000	11,000
8-23-77	20.0		8.3	1	350	0.1	14,000	230,000
8-30-77	24.5		8.4	0	325	2.0	17,000	8,600
9-07-77	21.0		7.9	1	370	1.2	29,000	25,000
9-21-77	19.0		7.8	1	400	0.4	8,000	18,000

Site 8.--Tulpehocken Creek at Bernville							
6-01-77	16.0	7.8	1	490	1.3	2,500	1,900
6-15-77	18.5	8.1	2	520	1.0	6,700	6,500
6-29-77	22.0	8.1	1	400	1.4	12,000	8,300
7-13-77	23.0	7.5	3	300	-	250,000	>100,000
7-26-77	22.0	8.2	2	520	0.7	4,800	7,000
8-10-77	24.0	8.1	2	480	0.8	2,200	2,700
8-23-77	20.0	7.8	2	475	1.2	13,000	11,000
8-30-77	23.0	8.1	1	480	0.8	2,600	3,300
9-07-77	19.5	7.9	2	520	0.3	6,300	19,000
9-21-77	19.0	7.8	2	475	0.4	1,900	5,200
Site 9.--Northkill Creek at Route 183 Bernville							
6-01-77	17.0	7.3	0	122	0.9	3,300	3,500
6-15-77	21.0	7.9	2	160	1.5	2,300	1,500
6-29-77	24.0	7.8	1	150	4.1	13,000	3,100
7-13-77	24.5	7.5	2	117	1.2	23,000	19,000
7-26-77	20.0	8.4	2	160	0.1	5,800	44,000
8-10-77	25.5	-	1	150	1.1	4,000	3,700
8-23-77	20.0	8.1	1	175	1.2	3,600	3,100
8-30-77	23.0	8.0	1	170	0.4	1,900	5,200
9-07-77	19.5	7.6	0	180	0.3	2,200	8,600
9-21-77	20.0	8.1	0	160	0.2	3,400	15,000**
Site 10.--Little Northkill Creek Upstream of Bernville							
6-01-77	17.0	7.1	0	190	0.0	1,800	87,000**
6-15-77	20.0	7.9	1	235	0.6	3,700	6,400
6-29-77	24.0	8.2	2	180	0.6	3,700	6,200
7-13-77	24.5	7.5	2	172	0.4	19,000	>50,000
7-26-77	22.0	8.5	2	210	0.6	3,500	5,600
8-10-77	24.5	-	1	200	0.4	800	2,100
8-23-77	19.0	7.9	2	245	0.8	2,500	3,200
8-30-77	24.0	7.6	1	228	0.2	1,000**	4,300
9-07-77	19.0	7.5	0	240	0.4	2,400	5,500
9-21-77	19.0	7.8	0	240	0.3	830	2,700

* Severity code 0=None, 1=Mild, 2=Moderate, 3=Serious, 4=Severe

** Best estimate based upon nonideal counting conditions

Table 4.--Physical and Bacteriological Analyses--Continued

Date Mo Day Yr	Water temperature (°C)	Discharge (ft 3/S)	pH (units)	Turbidity*	Specific conductance (micromhos per centimeter at 25°C)	FC/FS	Fecal coliform (col./100mL)	Fecal Streptococci (col./100mL)
Site No. 11.--Licking Creek at Mt. Pleasant								
6-01-77	14.0		7.4	1	304	1.3	6,000	4,800
6-15-77	17.0		7.6	1	320	2.8	4,000	1,400
6-29-77	19.5		7.8	1	255	4.1	13,000	3,200
7-13-77	20.0		7.8	0	305	7.7	37,000	4,800
7-26-77	19.0		7.9	0	340	0.6	2,900	5,200
8-10-77	19.0		-	0	300	0.5	1,900	3,800
8-23-77	17.0		7.8	0	300	2.7	13,000	4,900
8-30-77	24.0		7.9	1	298	0.2	1,000**	4,200
9-07-77	17.5		7.9	0	320	0.3	970	3,800
9-21-77	15.0		7.6	0	300	0.5	6,000	12,000
Site 12.--Spring Creek at Peacock Bridge								
6-01-77	16.0	20	7.6	1	340	<0.03	1,300	>50,000
6-15-77	17.5		7.8	2	320	1.00	2,100	2,100
6-29-77	22.0	17	8.1	1	265	2.3	11,000	4,600
7-13-77	22.0		7.6	3	242	0.9	33,000	35,000
7-26-77	20.0	15	7.9	2	300	0.6	2,500	4,000
8-10-77	23.0		-	0	350	0.1	1,700	32,000
8-23-77	19.0	16	8.0	1	360	0.9	3,600	4,100
8-30-77	23.0		8.0	1	365	0.9	3,400	3,600
9-07-77	19.0		7.7	1	350	0.4	4,500	13,000
9-21-77	18.5		7.7	1	355	1.5	2,600	1,700

Site 13.--Hospital Creek at Wernersville

6-01-77	18.0		7.5	1	270	0.2	590	2,500
6-15-77	16.0		7.7	1	275	2.1	8,800	4,200
6-29-77	20.5		7.5	1	210	0.9	1,300	1,400
7-13-77	21.0		7.6	3	230	1.5	26,000**	17,000
7-26-77	20.5		8.4	1	280	0.8	2,000	2,600
8-10-77	27.5		-	0	290	0.1	900	12,000
8-23-77	19.0		8.0	0	275	0.3	500	1,700
8-30-77	23.5		8.0	0	295	0.4	1,400	4,000
9-07-77	19.5		7.7	0	325	0.1	400**	4,300
9-21-77	13.0		7.4	0	305	0.5	1,500	3,000

Site 14.--Spring Creek near Robesonia

6-01-77	16.0		7.7	0	345	0.0	2,800	96,000**
6-15-77	15.5		7.7	1	335	1.1	16,000	14,000
6-29-77	18.0		7.6	1	270	1.2	13,000	11,000
7-13-77	19.5		7.6	3	249	4.6	73,000	16,000
7-26-77	17.5		8.2	3	360	0.3	9,000	35,000
8-10-77	22.5		-	0	410	0.3	1,800	5,600
8-23-77	16.0		8.4	2	375	0.2	22,000	95,000
8-30-77	18.0		8.0	2	420	0.2	5,700	29,000
9-07-77	15.0		7.8	1	435	0.6	11,000	20,000
9-21-77	14.5		7.6	0	420	>0.1	>20,000	36,000

Site 15.--Tulpehocken Creek at Rebers Bridge

6-01-77	16.0	141	7.6	2	450	0.0	730	28,000
6-15-77	17.0	122	8.3	3	480	0.8	2,100	2,700
6-29-77	22.0	110	7.9	2	325	<0.5	9,300	19,000
7-13-77	22.5	377	7.5	3	250	0.1	48,000	>100,000
7-26-77	20.5	54	7.5	3	380	0.1	30,000	280,000
8-10-77	24.5	42	8.0	2	430	0.4	700**	1,600**
8-23-77	20.0	85	8.0	2	385	0.6	12,000	20,000
8-30-77	24.0	28	8.3	2	415	0.8	800	1,000
9-07-77	22.0	62	8.1	2	490	1.6	1,600	1,000
9-21-77	19.5	68	7.7	2	405	.6	1,700	2,700

* Severity code 0=None, 1=Mild, 2=Moderate, 3=Serious, 4=Severe

** Best estimate based upon nonideal counting conditions

Influence of Precipitation, Discharge and Retention Time on Bacteria Populations

Precipitation and time of sampling are superimposed on the hydrograph for Tulpehocken Creek near the Blue Marsh dam site (Sta 01470960, Site 15) in figure 2. There were at least four storms of one inch or more during the study period. Sampling coincided with one such storm on July 13. It is noteworthy that on this date the samples from all stations contained bacteria populations far in excess of the mean.

Figure 3 shows the relation between discharge and fecal coliform density at site 15. The slope of the line indicates that even a small increase in discharge results in a large increase in the fecal coliform population. Better definition of the relation would be achieved by sampling frequently through the rise and fall of the stream during a storm.

Figure 4 depicts the "dieoff" curve of selected enteric bacteria in storm water stored at 20°C (Geldreich and Kenner, 1969). The application of the curve to the fecal coliform data collected at site 15 shows that the maximum density of 48,000 colonies per 100 mL will require a retention time of 12 days to be reduced to less than 200 colonies per 100 mL. On the basis of the relation between discharge and theoretical retention time for Blue Marsh Lake (fig. 5) (Barker, 1977), it appears that the 12 days retention necessary to reduce the population to acceptable densities will be met except when the discharge from the lake following a rainfall exceeds about 480 ft^3/s.

Fecal Coliform/Fecal Streptococci Ratio

A meaningful use of fecal streptococci measurements in assessing water quality has been through the correlation with the fecal coliform data. As reported by Geldreich and Kenner (1969), fecal coliform bacteria are at least 4 times more numerous than fecal streptococci in the feces of man. Conversely, fecal streptococci are at least 1.4 times more numerous than fecal coliform in farm animals, dogs, cats, and rodents.

In other words, a FC/FS ratio of 4 or greater indicates the presence of human waste while a ratio of 0.7 or less is indicative of animal wastes. Ratios between 0.7 and 4 probably represent a mixture of wastes. A ratio between 2 and 4 suggests a preponderance of human waste, and a ratio between 0.7 and 1.0 suggests a preponderance of livestock and poultry waste. A FC/FS ratio between 1 and 2 is difficult to interpret and may require sampling closer to the source. The correlations of FC/FS are most meaningful when applied to stream samples collected during the initial 24-hour contact with the receiving water.

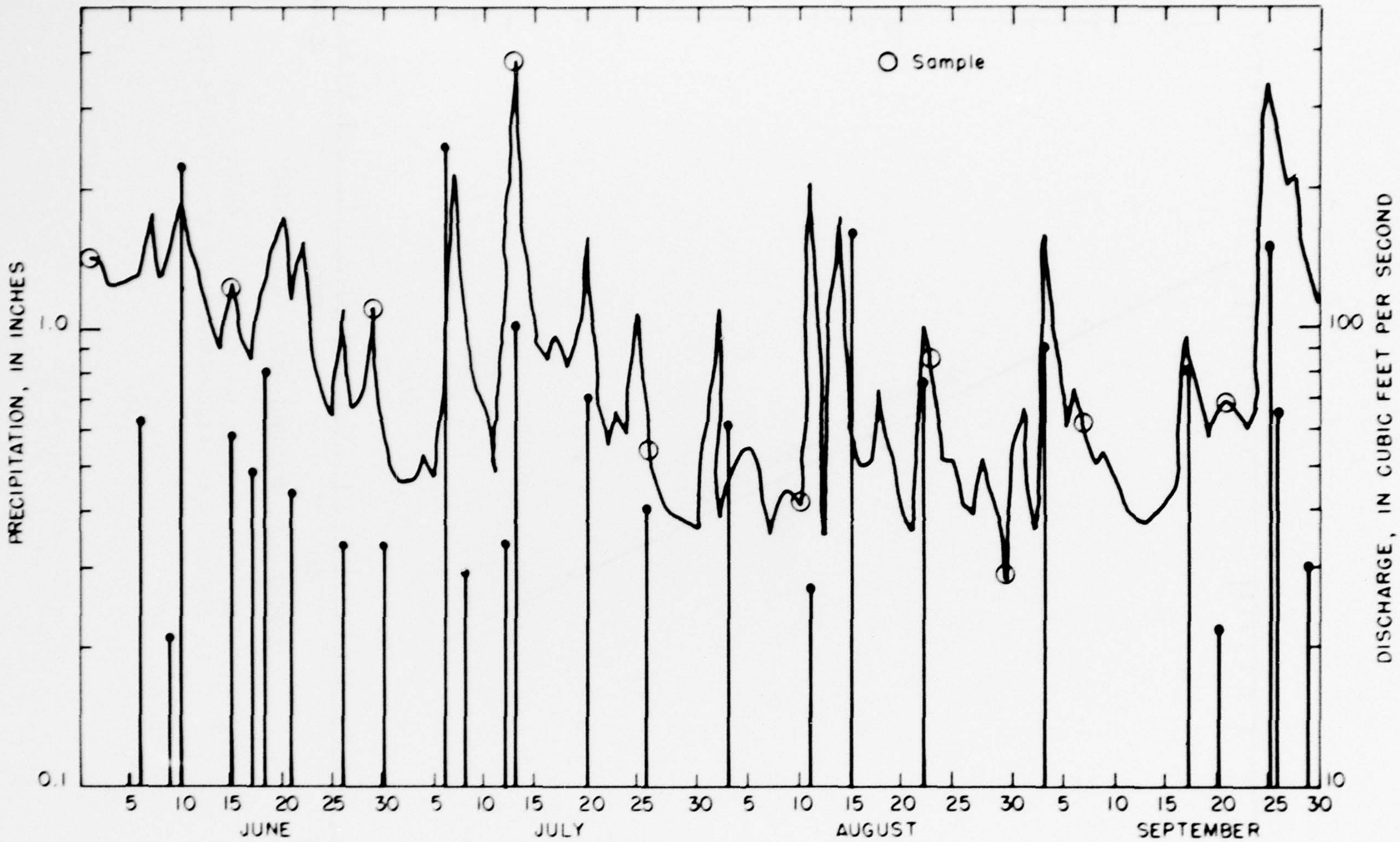

Figure 2.--Hydrograph for Tulpehocken Creek and precipitation near Blue Marsh Dam site, station 01470960

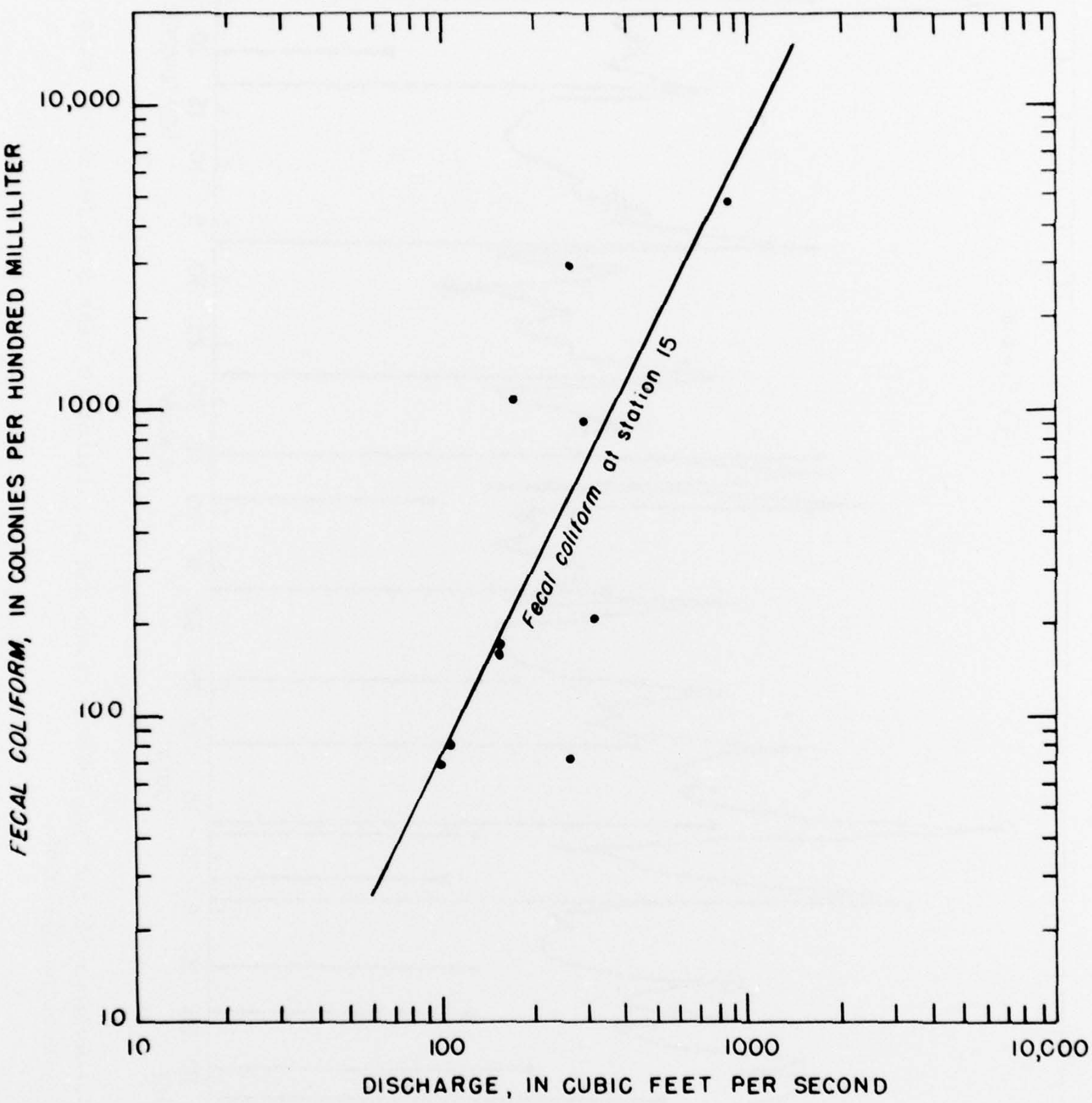

Figure 3.--Relation between fecal coliform density and discharge at Tulpehocken Creek at Rebers Bridge

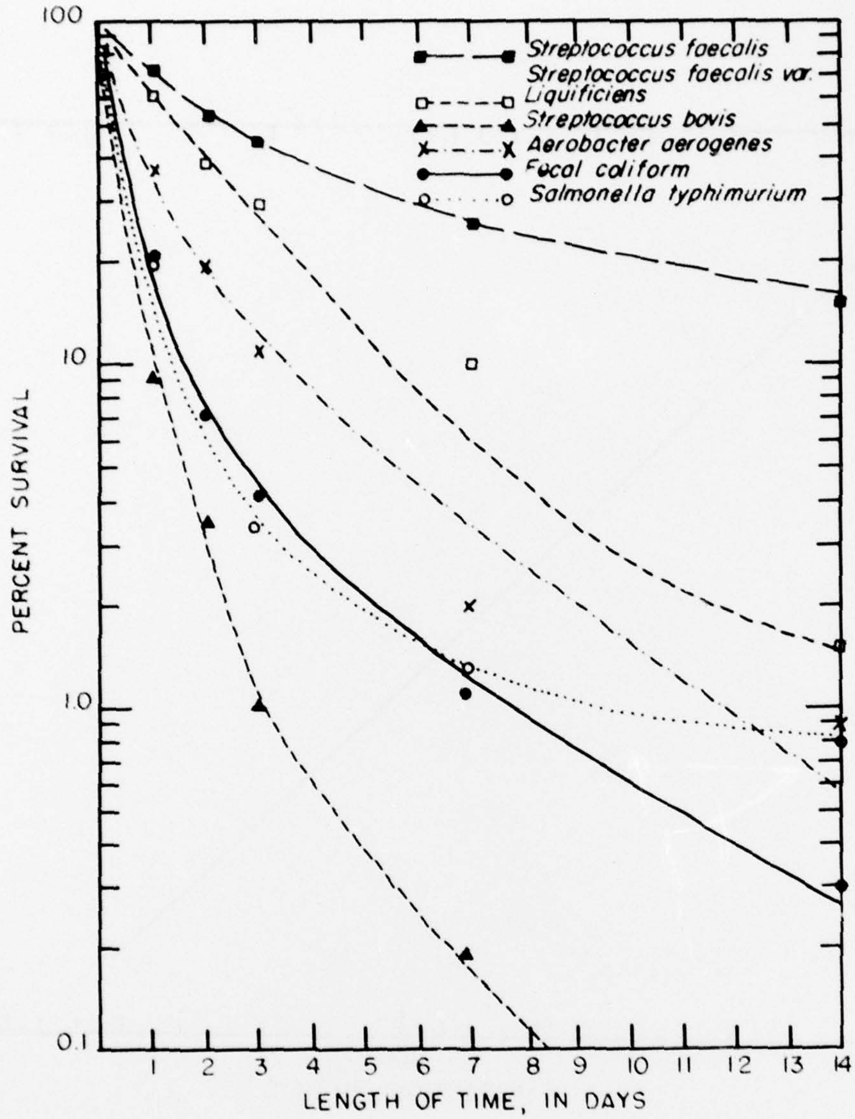

Figure 4.--Persistence of selected entric bacteria in storm water stored at 20°C (after Geldreich and Kenner, 1969).

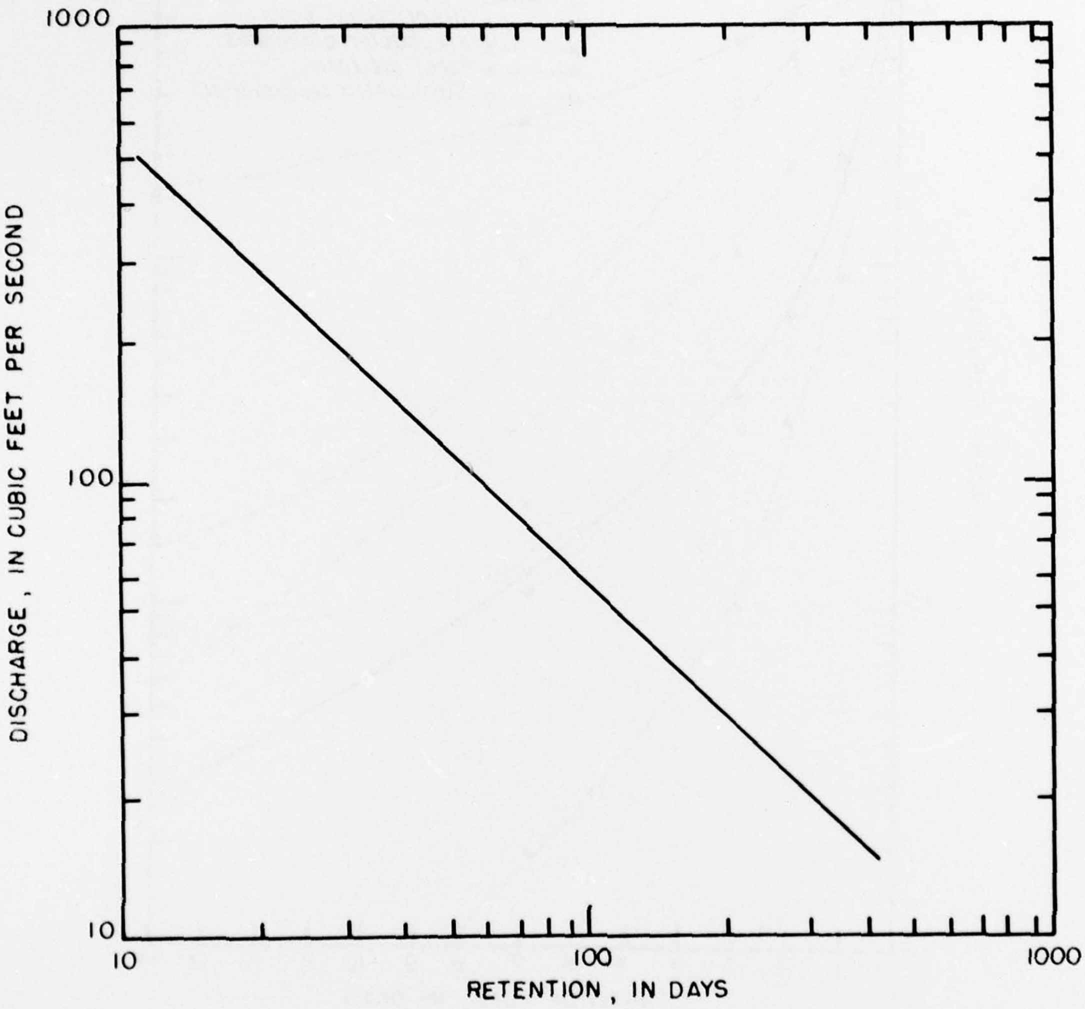

Figure 5.--Relation between discharge and theoretical retention in Blue Marsh Lake (Barker, 1977).

Table 5.--Frequency of fecal coliform/fecal streptococci ratios at 15 stream sites in the Tulpehocken Creek Basin

Site No.	Suggests Non-human source 0.7	0.7-1	Unknown 1-2	Suggests Human source 2-4	4
1	5	0	2	2	1
2	2	2	4	1	1
3	4	4	0	2	0
4	0	6	3	1	0
5	3	3	2	1	1
6	6	0	2	1	1
7	4	2	1	3	0
8	4	3	3	0	0
9	4	1	4	0	1
10	9	1	0	0	0
11	5	0	1	2	2
12	4	4	1	1	0
13	6	2	1	1	0
14	7	0	2	0	1
15	7	2	1	0	0
TOTAL	70	30	27	15	8

The correlations of fecal coliform to fecal streptococci at all 15 sampling sites (Table 5) support the belief that the majority of fecal waste entering the Tulpehocken Creek basin is from non-human sources. The fact that most sites have FC/FS ratios that vary from less than 0.7 to 4 or greater indicates a mixed population that, at times, contains a high proportion of human waste.

Summary and Conclusion

An investigation of the bacteriological content of Tulpehocken Creek basin reveals that (1) the current EPA and Commonwealth of Pennsylvania water-quality standards for bathing waters are being exceeded at some sites, (2) the non-point sources of enteric bacteria are the dominant factor in the excessive counts observed, and (3) the majority of enteric bacteria are of non-human origin.

It was further noted that Mill Creek near Sheridan, Tulpehocken Creek near Womelsdorf, Mill Creek near Kricks Mill, and Spring Creek near Robesonia frequently had high bacterial densities. Dairy cattle, horses, and other livestock are believed to be the dominant sources of these bacteria because pastures are commonly adjacent to streams throughout the basin.

Control of drainage from livestock areas, fencing of creek banks, and diligent monitoring of sewage treatment plants for assessing and correcting deficiencies are necessary in reducing the enteric bacterial populations in the Tulpehocken Creek basin to acceptable levels.

Based upon present enteric bacteria populations, estimated rate of die-off, and theoretical retention time in Blue Marsh Lake, a reduction in bacteria densities to meet water-quality standards may be expected during the June-to-September recreation season except during periods of intense rainfall and subsequent runoff.

Additional studies following closure of the dam would permit measurement of actual rates of bacterial survival during various hydrologic conditions which did not occur during this study. Variations of bacterial populations during storms should be documented. Such information could be used to correlate the populations observed with controlling variables indicated by data of this study.

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